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(54) Title of the Invention: Fine carbon particle removal device

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Specification

1. Title of the invention

Fine carbon particle removal device

2. Scope of the patent claims

(1) Fine carbon particle removal device characterized in that:

in an exhaust gas passage of an internal combustion engine there are provided capture means that capture fine carbon particles and that comprise a heat-resistant member having gas-permeability, and an oxidation catalyst;

and in that there are provided fuel injection means that supply fuel to the upstream side of said capture means and oxidation catalyst.

(2) Fine carbon particle removal device according to claim 1 characterized in that said oxidation catalyst also serves as said capture means.

(3) Fine carbon particle removal device characterized in that:

in an exhaust gas passage of an internal combustion engine there are provided capture means that capture fine carbon particles and that comprise a heat-resistant member having gas-permeability, and an oxidation catalyst;

and in that there are provided fuel injection means that supply fuel to the upstream side of said capture means and oxidation catalyst, and temperature detection means that detect the temperature of the exhaust gas, the supply of fuel being controlled in accordance with the temperature of the exhaust gas.

(4) Fine carbon particle removal device according to claim 3 characterized in that said oxidation catalyst also serves as said capture means.

(5) Fine carbon particle removal device characterized in that:

in an exhaust gas passage of an internal combustion engine there are provided capture means that capture fine carbon particles and that comprise a heat-resistant member having gas-permeability, and an oxidation catalyst;

and in that there are provided fuel injection means that supply fuel to the upstream side of said capture means and oxidation catalyst, and blockage detection means that detect blockage of said capture means, the

supply of fuel being controlled in accordance with the blockage condition.

(6) Fine carbon particle removal device according to claim 5 characterized in that said oxidation catalyst also serves as said capture means.

(7) Fine carbon particle removal device according to claim 5 or 6 characterized in that said blockage detection means detect pressure loss of said capture means.

(8) Fine carbon particle removal device according to claim 5 or 6 characterized in that said blockage detection means detect pressure loss of said capture means and the flow rate of the exhaust gas.

3. Detailed description of the invention

The present invention relates to a fine carbon particle removal device for the removal of fine particles whose chief constituent is carbon from the exhaust gas of an internal combustion engine of, for example, an automobile.

In some existing removal devices of this type, fine particles whose chief constituent is carbon (hereinbelow called fine carbon particles) are captured by a filter or cyclone or the like arranged in the exhaust system. It is also possible to arrange fine carbon particle capture means in the vicinity of the exhaust manifold, and to burn up the captured fine carbon particles by the heat of the exhaust gas.

However, if a filter is employed, there is the drawback that this gets clogged up, or if a cyclone is employed, there is the drawback that complete capture of the fine carbon particles is not achieved since these are light and small. Furthermore, in the case of burning up the captured fine carbon particles by the heat of the exhaust gas, in order to burn up the carbon, an exhaust gas temperature of at least about 600°C is necessary. However, when driving a vehicle in towns, driving conditions are scarcely ever such that the temperature of the exhaust gas gets above 600°C, so there is the drawback that the captured fine carbon particles do not get burnt up and blockage of the filter arises.

An object of the present invention is therefore to provide a fine carbon particle removal device whereby fine carbon particles can be captured and removed in a stable fashion during ordinary town driving.

The invention is described below with reference to embodiments illustrated in the drawings. In Fig. 1, 1 is an air intake manifold, 2 is a main engine body, 3 is an exhaust manifold, 4 is a fine carbon particle removal device according to the present invention, and 5 is an exhaust pipe. Removal device 4 according to the present invention is mounted immediately downstream of the exhaust manifold 3 and captures and removes fine particles of carbon etc. in the exhaust gas that is exhausted from engine 2. Hereinbelow, this removal

device 4 will be described in detail with reference to Fig. 2.

In Fig. 2, cylindrical main body 7 is made of stainless steel, and is fixed in the exhaust gas passage by flanges 7a, 7b, the exhaust gas flowing in the direction indicated by the arrow A. 8 is a filter consisting of glass wool; this is packed between a stainless steel gauze 10 (about 100 mesh) on the upstream side of this filter 8 and a stainless steel punched metal element 9 fixed by spot welding to main body 7 on the downstream side of this filter 8.

Stainless steel metal gauze 10 is spot-welded to stainless steel ring stay 11, and ring stay 11 is spot-welded to main body 7. An oxidation catalyst 12 employing platinum is provided on the upstream side of the interior of filter 8. This oxidation catalyst 12 is obtained for example by spraying an acid solution of platinum chloride on to the surface of the glass wool constituting filter 8 using a spray, and baking for about 30 minutes at 500 to 1000°C. 13 is a fuel injection nozzle that is screwed into stay 14 that is welded to main body 7. Fuel is pumped out from fuel tank 15 by fuel pump 16 and is fed into fuel spray nozzle 13 through valve 17.

Next, the operation of the above fine carbon particle removal device 4 will be described. Exhaust gas containing fine particles of carbon etc. is fed into removal device 4 from engine 2 through exhaust manifold

3 and exhaust pipe 5, and the fine carbon particles are captured on the upstream side of filter 8. Thereupon, when the fuel is injected from injection nozzle 13 upstream of filter 8, the injected fuel is oxidized and burnt by the oxidation catalyst 12, and by this heat the fine carbon particles captured on filter 8 are also burnt and removed.

As described above, with the fine carbon particle removal device of the present invention, since the fine carbon particles are burnt by utilizing the heat of combustion of the injected fuel, even if the temperature of the inflowing exhaust gas is at a temperature (about 300°C) below the temperature that is necessary for burning and removal of the fine carbon particles (experimentally, about 600°C), fully satisfactory removal of the fine carbon particles can be achieved. Valve 17 interrupts the supply of fuel, being operated in linked fashion with for example the key switch or accelerator pedal (not shown), so that, when the engine is stopped or when, during high load operation, the temperature of the exhaust gas is comparatively high, supply of fuel is stopped.

In this embodiment, a glass wool filter was employed as the fine carbon particle collection means, but any material having suitable gas-permeability and resistance to heat could be employed; also, platinum catalyst was employed as the oxidation catalyst but for example a catalyst of the platinum-rhodium type could

be employed, the essential requirement being that it should be a catalyst capable of oxidizing and burning the injected fuel.

Furthermore, although in this embodiment an injection nozzle was employed as fuel injection means, the essential requirement is that it should be capable of injecting fuel on the upstream side of the fine carbon particle collection means; the fuel may be any fuel that generates heat when burnt by the oxidation catalyst and for example the same fuel as is supplied to engine 2 may be employed.

Fig. 3 illustrates a second embodiment, in which a temperature detector 20 that detects the temperature of the exhaust gas and a control circuit 21 are added, the arrangement being such that the supply of fuel is controlled in accordance with the temperature of the exhaust gas. For this temperature detector 20 for example a chromel-alumel thermocouple is employed whose temperature sensing part is arranged on the upstream side of oxidation catalyst 12 and filter 8 within main body 7, being screwed into a stay 22 that is welded to main body 7. Control circuit 21 has the output of temperature detector 20 fed thereto through lead 23 and controls an electromagnetic valve 17 by means of its output such that if the output voltage of temperature detector 20 is above a set voltage, i.e. the temperature of the exhaust gas is above a set temperature (about 600°C), electromagnetic valve 17 is

closed, and if it is below the set temperature, electromagnetic valve 17 is opened. By this means, fuel is only injected when natural removal of the fine carbon particles cannot be achieved, i.e. when the exhaust gas temperature is less than 600°C, thereby enabling fuel consumption to be reduced. Although in this embodiment a chromel/alumel thermocouple was employed as temperature detector 20, a platinum/rhodium or the like thermocouple could be employed, or a temperature sensor such as a thermistor could be employed.

In the third embodiment shown in Fig. 4, the supply of fuel is controlled in accordance with the state of blocking up of filter 8 by fine carbon particles; pipes 30, 31 for pressure extraction are fixed by welding to main body 7 upstream and downstream of filter 8 and the pressures extracted by these respective pipes 30, 31 are fed to pressure detector 32, pressure detector 32 opening and closing electromagnetic valve 17 in accordance with the pressure difference thereof. Since the pressure difference between the upstream side and downstream side of filter 8, i.e. the pressure loss, gradually increases as more fine carbon particles are captured in filter 8, pressure detector 32 opens the fuel passage by opening the electromagnetic valve 17 when the pressure difference reaches a prescribed pressure (for example 200 mmAq), thereby introducing fuel into the removal device from fuel injection nozzle

13. The injected fuel is thereby oxidized and burnt by oxidation catalyst 12 and the heat thereof burns and removes the fine carbon particles captured on filter 8. When this happens, the pressure loss of filter 8 drops, and when this pressure loss becomes smaller than a prescribed pressure, pressure detector 32 opens electromagnetic valve 17 thereby stopping injection of fuel. In this way, the supply of fuel is controlled in accordance with the amount of fine carbon particles captured, so the amount of fuel consumed can be reduced.

It is sufficient if pressure detector 32 can interrupt power supply to electromagnetic valve 17 in accordance with the detected pressure difference, and it may comprise for example a combination of a known diaphragm and potentiometer or a combination of a semiconductor pressure gauge or the like and an electrical circuit that interrupts power supply in accordance with the output thereof.

The fourth embodiment, shown in Fig. 5, is an improvement on the third embodiment described above, whereby the state of blockage of filter 8 is detected more accurately than by detecting the flow rate of exhaust gas. Specifically, a stainless steel plate 34 having an orifice 33 is clamped between flange 7b of main body 7 and flange 5a of exhaust pipe 5 and fixed by means of a nut and bolt; pipe 35 for pressure extraction is welded to exhaust pipe 5 downstream of

orifice 33, and the pressure downstream of orifice 33 extracted by this pipe 35 is fed into pressure detector 32.

The operation of this embodiment will now be described. When exhaust gas from the engine is introduced into removal device 4, pressure losses (respectively ΔP_F and ΔP_O) are generated by filter 8 and orifice 33 in accordance with the rate of flow thereof. These pressure losses are detected respectively between pressure extraction pipes 30, 31 and pipes 31, 35. The abovementioned pressure loss ΔP_F is expressed by the sum of the pressure loss of filter 8 itself and the pressure loss due to blocking-up thereof, and is a function of the rate of the flow of gas through filter 8 at that time. Consequently, when the fluctuation of gas flow rate is small, the degree of blockage of filter 8 can be detected by measuring ΔP_F, but, when there is wide variation of flow rate, correction for the flow rate becomes necessary. The pressure loss ΔP_O due to orifice 33 is a function of flow rate, as is well known. Consequently ΔP_F and ΔP_O are fed to pressure detector 32 and the set pressure of ΔP_F at which electromagnetic valve 17 is opened is made larger as ΔP_O becomes larger, i.e. the set pressure is corrected in accordance with the flow rate of the exhaust gas. Detection solely of the amount of blockage of filter 8 can thereby be achieved, making it possible to inject fuel into the removal device 4 by

opening electromagnetic valve 17 when a fixed state of blockage of filter 8 has been reached. Although in this embodiment the pressure loss of orifice 33 was detected in order to determine the flow rate of exhaust gas, it would be possible for example to detect the pressure loss using a Venturi or filter having a suitable degree of gas-permeability, or to determine the flow rate directly by a Pitot tube or hot-wire anemometer etc.

In the fifth embodiment shown in Fig. 6, the method of arrangement of the oxidation catalyst is different from that of the first embodiment. Specifically, an oxidation catalyst 12a comprising platinum catalyst carried on a honeycomb-like carrier (about 200 mesh) made by Coachlight is provided upstream of filter 8; the circumferential surface of this oxidation catalyst 12a being held by a resilient stainless steel gauze 40, and the circumferential end faces being fixed by spot-welded ring stays 41, 42 to main body 7.

The operation of this embodiment is practically the same as that of the first embodiment. Fine carbon particles are captured on the upstream side of filter 8, and when fuel is injected from fuel injection nozzle 13 they are burnt by oxidation catalyst 12a, generating heat; by means of this heat, the fine carbon particles captured on the surface of filter 8 are burnt up and removed.

The sixth embodiment shown in Fig. 7 is similar to the fifth embodiment but the structure of the carrier of the oxidation catalyst is different. That is, oxidation catalyst 12b wherein platinum catalyst is carried on a γ-alumina pellet carrier of diameter 3 to 5 mm is arranged upstream of filter 8 and this oxidation catalyst 12b is held at its circumferential surface by resilient stainless steel gauze 50 and is packed between stainless steel punched metal element 51 that is spot-welded to main body 7, and stainless steel gauze 10. The operation of this embodiment is practically the same as that of the fifth embodiment.

In the seventh embodiment shown in Fig. 8, the construction of the fuel injection means is different from the embodiments described above. Specifically, a Venturi 60 is fixed by welding on the upstream side of main body 7, the tip of a fuel injection pipe 61 being exposed in the neck portion of Venturi 60, this pipe 61 being connected to fuel service tank 62 through a valve 17. In addition, one end of a pressure extraction pipe 63 opens into the piping upstream of Venturi 60, while its other end is connected with fuel service tank 62. Also, fuel service tank 62 is connected to fuel tank 15.

With the above construction, when valve 17 is opened, fuel is fed from fuel service tank 62 by the difference in the pressure upstream of Venturi 60 (pressure at the aperture of pipe 63) and the pressure at the tip of

fuel injection nozzle 61, being thereby injected through fuel injection nozzle 61. This injected fuel is burnt by oxidation catalyst 12 and by means of the resulting heat the fine carbon particles that were captured are burnt up and removed. Fuel corresponding to the fuel consumed by injection is replenished from fuel tank 15.

Fig. 9 shows an eighth embodiment. Three filters 8a, 8b [sic] are provided, constituted by press-molding stainless steel gauze; between these filters 8a, 8b, 8c, oxidation catalyst 12c is provided in which platinum catalyst is carried on alumina balls of diameter about 5 mm, these alumina balls being fixed so that they are not in mutual contact. Oxidation catalyst 12c is positioned as far as possible on the upstream side within filters 8a, 8b, 8c.

Since with this construction the catalyst carriers are constituted such that they do not come into contact with each other, scarcely any damage to the carriers is produced by engine vibration or the like and they can thus be used over a long period. Also, since the catalyst layers are in a multi-layer construction, even if some fuel is present that was not burnt in the first layer, it is burnt in a subsequent layer, so any possibility of unburnt fuel being exhausted is eliminated.

It should be noted that, although in the present embodiment a filter constituted by press-molding

stainless steel gauze was employed as the fine carbon particle capture means, any means can be employed so long as it has resistance to heat and suitable gas-permeability and can be fixed such that the catalyst carriers do not come into mutual contact. Also, although alumina balls were employed as the catalyst carrier, there is no restriction regarding material or shape, the essential requirement being that carrying of the catalyst is effected easily and that the material should have excellent durability and resistance to heat; any such material can be used. Furthermore, although two catalyst layers were described, one or three or more layers could be employed.

Fig. 10 shows a ninth embodiment. Oxidation catalyst 12d constituted by carrying platinum catalyst on alumina pellets (diameter less than about 3.5 mm) is packed between stainless steel punched metal elements 9a, 9b; this also serves as fine carbon particle capture means on this oxidation catalyst 12d.

In this way, when exhaust gas containing fine particles of carbon etc. is introduced into removal device 4, the fine carbon particles are captured by oxidation catalyst 12d. Thereupon, when fuel is injected from fuel injection nozzle 13, the injected fuel is oxidized and burnt by oxidation catalyst 12d and by means of this heat the fine carbon particles

captured on oxidation catalyst 12d are burnt up and removed.

It should be noted that, although in this embodiment alumina was employed as catalyst carrier, any heat-resistant ceramic material could be employed (for example mullite or cordierite). Also, the shape of the carrier is not restricted to pellets but could be Raschig rings or the like, the essential requirement being that it should be a shape whereby fine carbon particles in the exhaust gas can be captured to some degree.

In the devices of the embodiments shown in Fig. 6 to Fig. 10, a combination of constructions may be employed to control supply of fuel in accordance with the state of blockage of the filter and/or the exhaust gas temperature, as shown in Fig. 3, Fig. 4 and Fig. 5.

It is also possible, in all the embodiments described above, to employ the removal device 4 for capturing the fine carbon particles contained in recycled exhaust gas by providing it in the path whereby exhaust gas is recycled to the intake system. If this is done, it is preferable that removal device 4 is arranged upstream of a so-called EGR valve that opens and closes the recycling path.

As is clear from the above description, according to a first aspect of the invention, the benefit obtained is that fine carbon particles can be continuously captured even when the temperature of the exhaust gas

is comparatively low. Also, with the second aspect of the invention and third aspect of the invention, in addition to the above benefit, the benefit obtained is that supply of fuel can be effected in appropriate manner, enabling the fuel consumption to be reduced.

4. Detailed description of the drawings

Fig. 1 is a diagram illustrating an example of the position of installation of a device according to the invention. Fig. 2 to Fig. 10 are cross-sectional views illustrating first to ninth embodiments of the device of the invention.

2... Internal combustion engine, 4... Fine carbon particle removal device, 8, 8a, 8b, 8c... Filters constituting capture means, 12, 12a, 12b, 12c... Oxidation catalysts, 12d... Oxidation catalyst also serving as capture means, 13... Fuel injection nozzle constituting fuel injection means, 20... Temperature detector, 32... Pressure detector constituting blockage detection means, 61... Fuel injection pipe constituting fuel injection means.

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